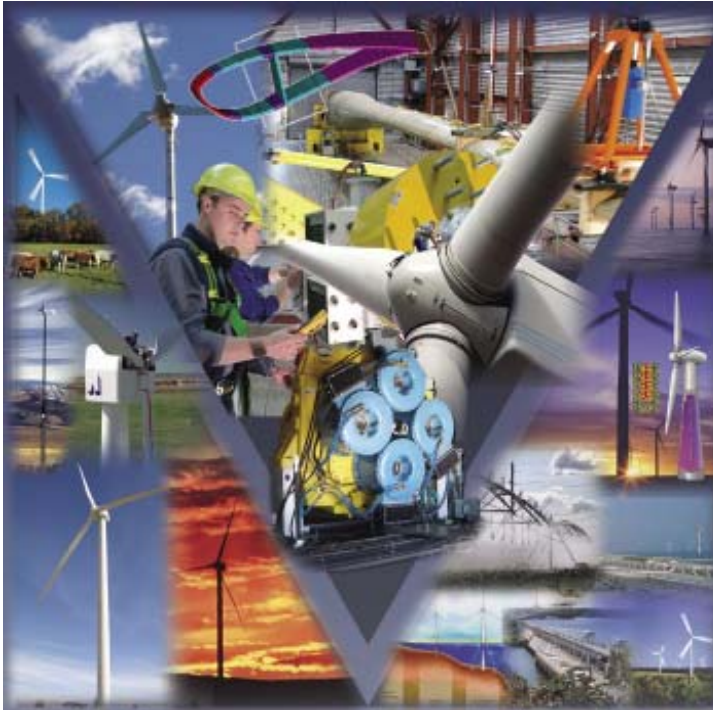


1.0 Wind and Hydropower Program Overview



The Wind Energy Program is one element of the U.S. Department of Energy (DOE) Wind and Hydropower Technology Program (WHTP) under the Office of Energy Efficiency and Renewable Energy (EERE). EERE leads the Federal government's research, development, and deployment efforts in energy efficiency and renewable energy.

In May 2001, the President's National Energy Policy Development Group released a National Energy Policy (NEP)¹ containing a set of recommendations that have

become the cornerstone of U.S. energy policy under the George W. Bush Administration.

In support of NEP, EERE published a Strategic Plan in October 2002 that describes nine strategic priorities.² These include reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, increasing the efficiency of buildings and appliances, reducing the energy intensity of industry, and creating a domestic renewable energy industry. The most important strategic goal for the Wind Energy Program is to: "Increase the viability and deployment of renewable energy technologies."

The program works to support this specific goal by:

- Increasing the viability of wind energy by developing new cost-effective technology and increasing the reliability of all large wind technology; developing cost-effective distributed, small-scale wind technology; and performing research that supports these technology viability activities.

¹ National Energy Policy, National Energy Policy Development Group, Government Printing Office, Washington, D.C. ISBN 0-16-050814-2, May 2001. <http://www.ne.doe.gov/pdf/National-Energy-Policy.pdf>

² U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy mission, http://www1.eere.energy.gov/office_eere/mission.html

- Increasing the application of wind energy by helping facilitate the installation of wind systems through supporting research and outreach in power grid integration, transmission, technology acceptance, systems engineering, and analytical support.

Through a partnership with the DOE Office of Electricity Delivery and Energy Reliability, the program is also actively working to address EERE's fourth strategic priority to, "increase the reliability and efficiency of electricity generation, delivery, and use."

The NEP was further strengthened by the release of the President's Advanced Energy Initiative³, which was unveiled during the 2006 State of the Union Address. This document lays the foundation of a national strategy to change the way we power our homes, offices, and vehicles, and to eliminate our unhealthy addiction to oil. The document calls specifically for expanding the generation of clean energy from wind through activities to:

"Improve the efficiency and lower the costs of conventional wind turbine technologies; it will also help develop new small-scale wind technologies for use in low-speed wind environments."

The Initiative also recognized wind energy's potential contribution to the nation's energy solution by stating that:

"Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States."

DOE's efforts to achieve the mission, as defined above, are further focused by Section 931 of the Energy Policy Act (EPAcT) of 2005⁴, which directs that:

"The Secretary shall conduct a program of research, development, demonstration, and commercial application for wind energy, including-- low speed wind energy; offshore wind energy; testing and verification (including construction and operation of a research and testing facility capable of testing wind turbines); and distributed wind energy generation."

The Wind and Hydropower Technologies Program has interpreted the Presidential directive to "change the way we power our homes and businesses" and the implementation focus of EPAcT 2005 as a mission to provide leadership to the wind industry and assign higher priority to removing barriers to the use of advanced wind technology, which is intended to speed deployment into all wind regimes.

³Advanced Energy Initiative http://www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf

⁴ Energy Policy Act of 2005. <http://www.energy.gov/about/EPAcT.htm>

The program's FY 2007-2012 plan contains a number of shifts in priorities and activities to reflect this increased leadership and new direction. These shifts include:

1. Increasing the program's efforts to overcome near-term deployment barriers in the areas of grid integration and environmental issues.
2. Initiating a dedicated effort to enhance the Nation's energy infrastructure to allow expanded use of wind technologies through increasing access to transmission.
3. Expanding work in the area of turbine performance and reliability to mitigate risk in response to investor, developer, and operator concerns.
4. Broadening program activities in the distributed wind technology market sector (residential, farm, small business) by continuing work on small turbine technology development and supporting community wind projects and turbine applications connected to the distribution side of the grid. This will take advantage of significant grass-roots support for wind energy, and help provide the average American with a method to control their energy costs, support local economic development, and help secure the Nation's energy future.
5. Reducing the use of cost-shared private-public partnerships for the development of large wind systems based on the current strength of the wind market. Although partnering with industry is important, the program will shift to an industry partnering strategy based on cost-neutral Cooperative Research and Development Agreements (CRADA) to match the maturing needs of a sustainable industry and better leverage program investments.
6. Reducing the scope of the program's efforts to develop offshore wind technology to allow for assessment of the potential market and the technical challenges to its development.

The program is developing an industry vision report in conjunction with the American Wind Energy Association (AWEA) and the National Renewable Energy Laboratory (NREL) that will help to further refine and redirect the Wind Energy Program's future plans.

1.1 Program History

The Federal Government has sponsored wind energy research since 1972. The early program, at the National Science Foundation, was driven by the needs of electric utilities and by the potential of wind as a "fuel saver" during the oil crisis. This utility focus led the program to conduct R&D activities on the development of large-scale wind turbines. All federal wind activities were centralized within the Department of Energy in 1977 following its creation.

In the early 1970s, analysts believed that large turbines had a strong potential for economies of scale, meaning that energy production would be increased by tapping better resources using taller towers and that utilities would primarily be interested in larger units. When the program began, the feasibility of using large wind turbines (defined as turbines rated at 100 kilowatts [kW] or larger) for grid-tied generation had not been established. The Mod-0 turbine, installed in 1975, and its variant, the Mod-0A, a 100-kW

turbine that operated at four sites, proved the feasibility of large-turbine technology. These early turbines provided a test bed for further innovation and paved the way for the development of the first multi-megawatt turbines. The 3.2-megawatt (MW) Mod-5B (Figure 1) was the largest and last turbine in the Mod series.



Figure1. The 3.2-MW Mod-5B, was the largest turbine in the Mod series.

Power systems engineering has been integral to the Wind Energy Program since the early 1970s. Every experimental wind turbine developed since the 100-kW Mod-0A has had a system integration study performed prior to its installation to address concerns over the variable output of wind energy. Utility operators were concerned that a wind turbine array would impose additional generation costs for which conventional units would be required to compensate. Another concern was that a cascading failure would occur if the array shut down during a storm with winds above the maximum safe operating range of the turbines.

Between 1981 and 1985, California became a pioneer in wind power development as a result of favorable development incentives and regulatory reforms (Figure 2 provides a chronology of developments in the post-1980 era). The turbines used in these early commercial installations were much smaller than the systems developed by DOE's large turbine research. Industry developed these

small systems to reduce risk in the absence of modeling and design tools.

The incremental approach taken by the small turbine manufacturers allowed extrapolation of lessons learned to machines of increasing size and sophistication, while taking advantage of available policy support. When new installations began declining in 1986 because of a reduction in tax credits and California market incentives, many U.S. manufacturers were forced to declare bankruptcy. As a result of this decline and budget reductions, power systems analyses and wind technology application became low-priority R&D areas for the program during the late 1980s and early 1990s.

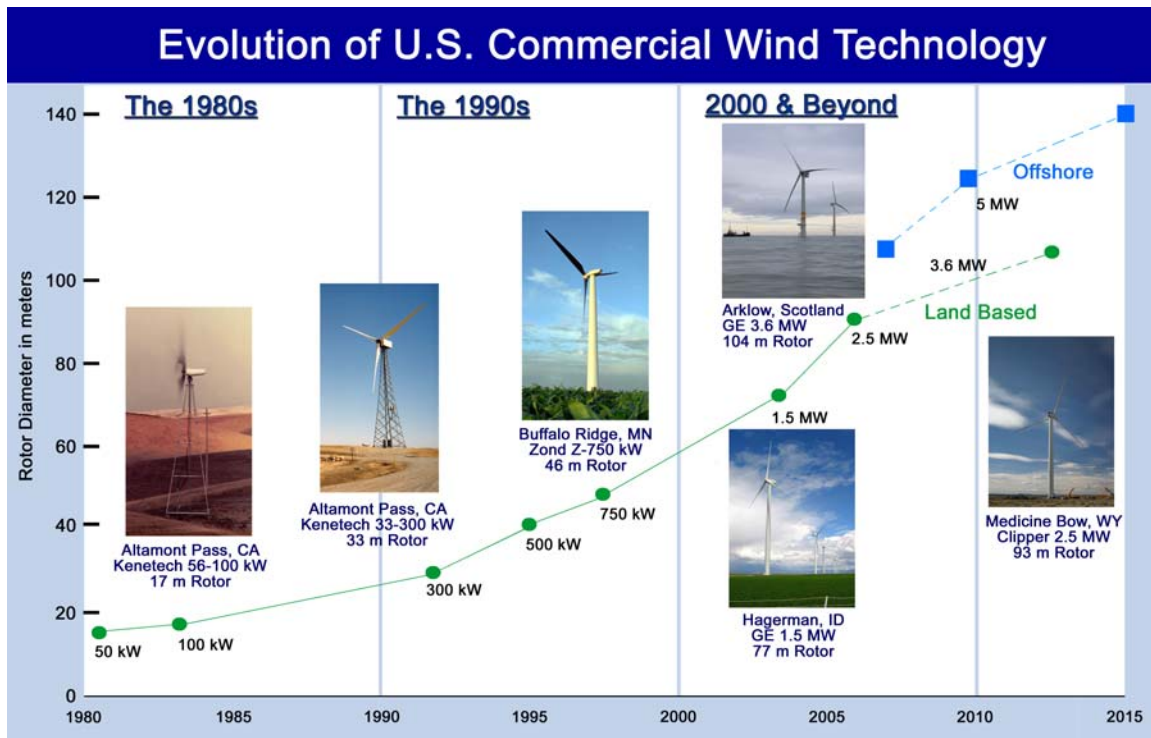


Figure 2. Wind technology developments beginning in 1980.

In 1990, the program developed a new strategy that focused on collaborative activities with utilities and industry. This new emphasis was based on experience gained from earlier R&D activities and guidance from the National Energy Strategy (NES) that was developed in 1989 and 1990. An important element of that strategy was to expand the use of wind energy beyond California. To that end, four objectives were adopted: (1) maintain the existing generation of turbines, (2) increase industry competitiveness, (3) upgrade the research base, and (4) develop advanced wind turbines.

The Advanced Wind Turbine (AWT) Program was initiated by DOE in 1990 to assist the U.S. industry in incorporating advanced technology into its wind turbine designs. The first phase of the AWT Program, Conceptual Design Studies, was completed in 1992^{5,6,7,8,9,10}. This activity identified and evaluated improvements intended to make

⁵ Hock, S. M.; Thresher, R. W.; Goldman, P. R. (1991). Federal Advanced Wind Turbine Program. 5 pp.; NREL Report No. TP-257-4625. (Available on request)

⁶ Butterfield, C. P.; Smith, B.; Laxson, A.; Thresher, R.; Goldman, P. (1993). DOE/NREL Advanced Wind Turbine Development Program. 5 pp.; NREL Report No. TP-442-5415. (Available on request)

⁷ Swift, A.; Hock, S. M.; Thresher, R. (1993). Advanced Wind Turbine Performance and Cost Projections: A Configuration Study. Windpower '92: Proceedings of the American Wind Energy Association Conference, 19-23 October 1992, Seattle, Washington. Washington, DC: American Wind Energy Association; pp. 431-447. (Available on request)

⁸ Hughes, P.; Sherwin, R. (1994). Advanced Wind Turbine Design Studies: Advanced Conceptual Study, Final Report. 266 pp.; NREL Report No. TP-442-4740. (Available on request)

⁹ Advanced Wind Turbine Conceptual Study: Final Report, August, 1990 - March 1992. (1995). 518 pp.; NREL Report No. TP-441-6924(Available on request)

¹⁰ Advanced Wind Turbine Near-Term Product Development: Final Technical Report. (1996). 135 pp.; NREL Report No. TP-441-7229. (Available on request)

existing wind turbines more competitive. It also explored advanced configurations that would be competitive for bulk-electricity generation at sites with moderate wind speeds. Studies indicated that these advanced configurations were capable of achieving substantial improvements in performance, reliability, and cost of energy.

The second phase of the AWT Program, Near Term Product Development, lasted for nearly 4 years. This effort involved the fabrication and testing of prototype turbines designed to produce electricity for \$0.05/kilowatt-hour (kWh) or less in Class 4 sites (sites with winds of 5.8 meters per second (m/s) [13 mph]) in the near term. These products were intended to bridge the gap between earlier technologies and the next generation of utility-grade turbines.

The third phase of the AWT Program, Next Generation Product Development, stimulated U. S. industry to explore new concepts and to apply cutting-edge technology to the development of prototype utility-grade wind turbine systems. The objective was to produce electricity for \$0.03/kWh or less at Class 6 sites (sites with winds of 6.7 m/s [15 mph]). Of the two turbines developed under this activity, the Enron Wind 1.5 MW unit (now owned and produced by General Electric) proved to be a very successful commercial product.

As a companion to the large turbine development projects, beginning in the 1990s the program also supported the development of more cost-effective small-scale turbines (less than or equal to 100 kW) for the distributed-generation market. Two principal products were developed under this effort. The Atlantic Orient Corporation produced a 50-kW, three-bladed downwind machine, and Northern Power Systems developed a 100-kW direct-drive turbine for cold weather environments.

Interest in power engineering and systems integration was revived in the mid-1990s, when NREL assumed the technical lead. Since then, research has centered on: estimating a wind plant's contribution to system reliability, often called capacity credit; studying the challenges of ancillary services; and collecting high-rate real power, reactive power, and voltage data to establish the short-term output variations of a wind plant. One study on high-rate real power performed at the Lake Benton II project shows that the wind output varies little in the short-term and has minimal impact on system costs. Another study performed in the Northern States Power System network looked at ancillary costs and found that an additional system cost of 0.18 cents per kWh was imposed by wind variability on 300 MW or 4% of the wind penetration in that area. A 2004 study indicated additional operating costs of about 0.46 cents/kWh for a 15% penetration level in the Xcel Energy power system network. The program continues to play a key oversight and supportive role in the development of regional wind impact studies while working with organizations such as the Utility Wind Integration Group (UWIG) to obtain a more expansive understanding of wind/grid integration issues.

In 2001, the National Wind Coordinating Committee (NWCC) began holding regional transmission issue forums to allow grid stakeholder dialog and wind sector input to transmission planning groups. These efforts have resulted in many gigawatts (GWs) of

wind being considered in conventional regional grid expansion efforts. In 2002, the Wind Energy Program initiated a systems integration project to address technical issues that may limit wind in the marketplace and provide a clearinghouse for research-based information for utilities, cooperatives, and other industry stakeholders on the integration of wind technology into the nation's power system.

Prior to the establishment of the Wind Powering America (WPA) Project in 1999, there were only limited Federal efforts to support the use of wind energy. Most efforts were centered in California and Minnesota, both of which had state policies that made wind energy an attractive option. Development was limited to these two states despite better wind resources in other states, particularly the rural plains states. The founding of the NWCC created a national forum for discussion of national-level issues affecting the U.S. wind industry, including wind/avian interactions and siting lessons for wind project developers.

Since that time the U.S. wind industry has grown from approximately 2500 MW of installed wind capacity with limited annual growth to current installation of more than 11,000 MW by the end of 2006, and has experienced an average annual rate of growth of more than 20%. Additionally, the number of states with over 100 MW of installed wind has grown from 4 in 1999 to 19 today.

Based on the Advanced Energy Initiative, the Energy Policy Act of 2005, direction of new EERE executive leadership, and guidance from industry partners, the program initiated a shift in focus to more equally weight the programs activities between technology development and acceptance activities, beginning in 2006. As has been described in the last section, this shift reduces emphasis on research activities in the area of offshore wind and on larger private/public partnerships for the development of new large wind systems. In place of these activities, the program is greatly expanding work in wind integration and transmission, enhancing work in technology acceptance and siting, and expanding work in small wind systems to include all distributed wind technologies, such as community wind.

1.2 Market Overview and Federal Role of the Program

Although facing challenges, wind energy is becoming a favored renewable energy technology for utility-scale power generation and a popular alternative in smaller distributed applications. With total installations at the end of 2006 of more than 11,000 MW, almost 5,000 MW of which were installed in 2005 and 2006, the wind energy market is expanding rapidly. As a result of the extension of the Renewable Production Tax Credit (PTC) included in EPAct 2005, similar growth rates are expected through 2008.

Wind has the potential to provide a significant portion of the new generation needed to respond to growing domestic demand for electricity, which is projected to increase at an annual rate of 1.4% through 2025. Although wind energy accounted for less than 1% of total national generation at the end of 2006, it provides carbon free, environmentally safe,

and domestically secure energy at a cost at or below 4 to 9 cents per kWh in varying wind speed classes. Distributed wind systems also allow communities, businesses, and average Americans to take an active role in determining the Nation's energy future. Wind energy has also shown itself to be a strong contributor to building local economies through fees paid to landowners, creation of local businesses and new jobs, and an increased local tax base for rural counties and communities. The wind energy market has grown at an average of 26% annually for the past 6 years, attracting increasing attention from energy market participants, including the financial community, utilities, policy makers, media, and electricity consumers.

As the market environment for wind turbines has changed, so have the challenges of competing in the marketplace. Although wind historically has competed predominantly against natural gas production, as a nondispatchable electricity supply option wind now must frequently compete with the marginal operating costs of the local utility. This means that the variable operating costs of existing baseload power (often coal and nuclear) are often the basis of competition. Despite rising natural gas fuel costs, wind energy will continue to have to overcome a high capital investment intensity and relatively low capacity factor. However, the higher cost of natural gas generation resulting from the projected increase in demand for imported natural gas over the next 20 years may increase reliance on and cost competitiveness of wind-generated electricity.

As the wind power market continues to expand, the industry faces challenges that include the perception that the technology is risky, cost of energy, burdensome grid interconnection requirements, a challenging regulatory and policy environment, utilization of accessible high wind speed sites, limited transmission infrastructure, increased environmental scrutiny, resistance to visual impacts, and possible interference with radar installations (Table 1). Among these challenges, perceived risk, interconnection requirements, and the challenging regulatory and policy environment stand out, as they will determine whether wind will be afforded the opportunity to compete with other energy options under equitable rules, or whether wind will be put at a disadvantage to other technologies.

The increasing maturity of the U.S. market is being driven by several factors that include reductions in the cost of wind energy, public and policy support for alternative energy sources, and recognition of the price hedge that wind energy can provide against rising natural gas prices. Over the past 20 years, a strong DOE-funded R&D effort combined with private partnerships has lowered the base cost of wind energy from around 80 cents/kWh to as low as 4 cents/kWh. When combined with the PTC, which provides an incentive of 1.9 cents/kWh for the first 10 years of a project, and other tax considerations, the cost of wind energy becomes very competitive, and is sometimes lower than conventional generation sources.

Table 1. Wind Energy Market Barriers	
Perception of risk	Although at good site wind can supply electricity at prices lower than conventional technology, generally, new technology must be available at a cost significantly lower for the market to openly accept it due to the perceived higher risk of the new technology.
Higher cost of wind energy	Although the cost of energy from wind is comparable to new conventional technologies, the rising costs associated with the development of wind energy require further reductions of between 10% and 20% of total system cost to allow wind to develop to its full potential.
Burdensome grid interconnection requirements	Transmission constraints, unfavorable operational policies, and a lack of understanding of the impacts of wind energy on utility grids are major barriers to wind energy development.
Utilization of accessible high wind speed sites	As sites with excellent wind resources close to load centers or existing transmission infrastructure are developed, improvements must be made to allow cost-effective access to sites with lower wind speeds.
Limited transmission infrastructure	Transmission infrastructure limitations hinder the use of high-quality wind resources located far from demand centers.
Challenging regulatory and policy environment	Unclear regulatory approval processes at the Federal, state, and local levels complicate and raise the costs for the development of wind projects.
Increased environmental scrutiny	The impacts of wind turbines on avian and bat populations at some sites have caused concern.
Public acceptance	Some communities object to the real and perceived local impacts of both land-based and offshore wind farms.

Public and policy support for renewable generation in the face of rapidly fluctuating energy prices and environmental concerns develops primarily at the state level. Wind related financial policies include state-sponsored Renewable Portfolio Standards (RPS), generation payments and grants combined with the Federal PTC, U.S. Department of Agriculture (USDA) grants and loans, and new Clean Renewable Energy Bonds (CREB).

By the end of 2006, 22 states and the District of Columbia had RPS requirements that mandate the use of renewable power for a certain portion of the state's needs. Texas leads the way with its requirement of 5880 MW of renewable energy by January 1, 2015. Because wind energy is the least expensive renewable energy technology, it is widely used to supply the burgeoning green credit market and fulfill state-based RPS requirements.

In addition to development of large bulk-power generation, state-based RPS policies have been a major driver for the uptake of distributed wind technologies. As with large wind technologies, research on distributed wind systems has been a part of the program since its inception. Although current research on small wind turbines (less than 100 kW) is expected to be completed in FY 2007, opportunities for wind technology in distributed applications, either connected at distribution voltages or completely off-grid, appear to be

substantial.¹¹ Initial studies conducted by the program indicated that distributed wind technologies, including community, rural business applications, and residential wind should represent more than 5,000 MW by 2020.

Enacted in 1992, the PTC currently provides a 1.9 cent/kWh tax credit for electricity produced by commercial wind generation plants to help them compete with other generation technologies. The PTC has supported the rapid growth in wind power over the past 10 years. It is the principal Federal financial policy responsible for the installation of nearly 12 GW of wind in the United States. As a significant and direct financial incentive, the PTC has dramatically influenced wind energy investment decisions. Although the PTC has stimulated a large amount of wind development, Congress has allowed the PTC to lapse on several occasions, creating a series of biennial boom-and-bust cycles (Figure 3) that have not provided a stable business environment in which companies can thrive. The result has been annual cycles of significant swings in manufacturing demand and turbine installations. These swings in demand have discouraged companies from investing in new U.S.-based manufacturing capacity, pushing up costs and subjecting the U.S. market to foreign exchange-related cost fluctuations for equipment imported from Europe. The PTC is currently authorized through calendar year 2008.

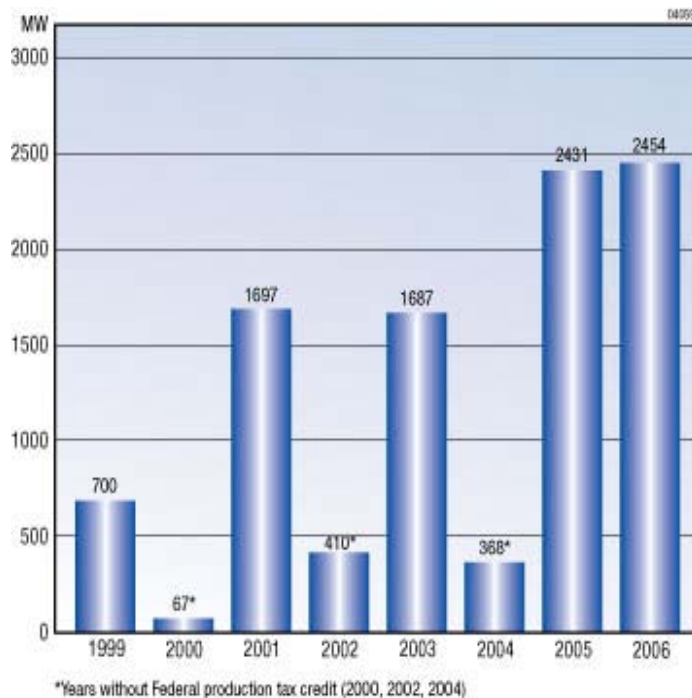


Figure 3. Wind capacity growth slowed drastically during the years when the PTC was allowed to lapse.

¹¹ U.S. Small Wind Turbine Industry Roadmap. (2002). 36 pp.; NREL Report No. BK-500-31958; DOE/GO-102002-1598 <http://www.nrel.gov/docs/gen/fy02/31958.pdf>

While the use of wind energy in the U.S. electric sector has increased, wind's use overseas has burgeoned. The European market, especially in Germany, Denmark, Spain, Italy, and the Netherlands has been driven by national policy mandates that provide attractive cost structures for wind-generated electricity. Wind is also a major energy supplier in India and China. The total installed capacity of wind technology worldwide was 71,146 MW at the end of 2006 (Figure 4) based on WindPower Monthly, which shows a slightly different total U.S. installed capacity than estimates completed by DOE and the American Wind Energy Association.

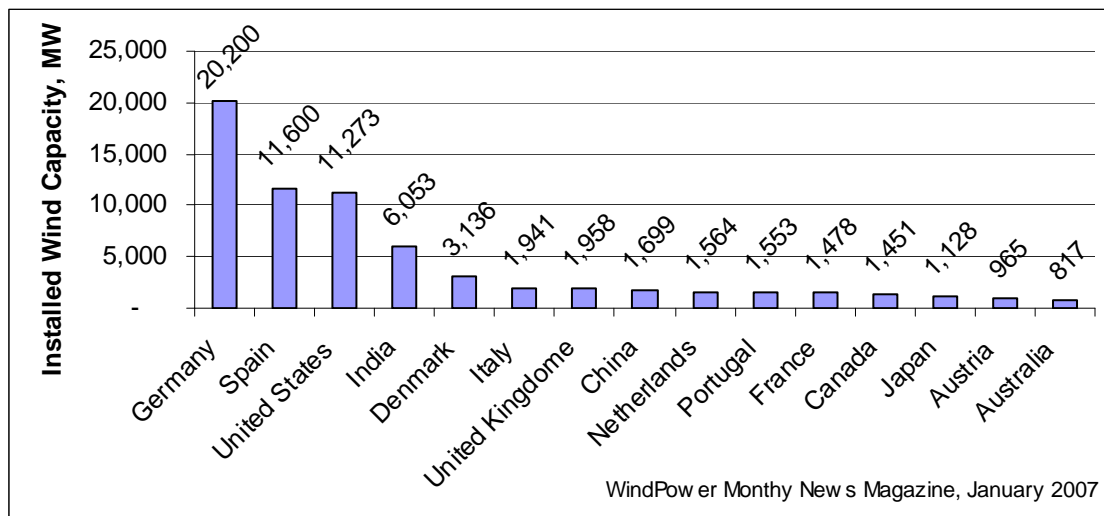


Figure 4. Top 15 countries based on total wind installations

The United States faces many challenges as it prepares to meet its energy needs in the twenty-first century. Electricity supply crises, such as those in California; fluctuating commodity, natural gas, and gasoline prices; heightened concerns about the security of the domestic energy infrastructure and foreign supply sources; and uncertainties about the outcome of electric industry restructuring all present challenges to energy policymakers.

As one of the most viable renewable energy sources on the market today, wind energy can play a strong role in meeting our nation's energy needs, addressing many of the issues currently facing energy policymakers. Studies commissioned by EERE in response to the Government Performance and Results Act (GPRA)¹² show that with the successful implementation of the Wind Energy Program, this clean renewable resource could represent approximately 50% of all new electric generation resulting from the different generation technologies in the EERE portfolio—almost 1000 billion kWh per year by 2050,. This comparison may not be appropriate for some programs focused on conservation or conversion to alternative technologies such as hydrogen; therefore, a comparison on annual CO₂ savings may be more indicative of wind's potentially enormous contribution. Based on the results of the analysis conducted for the FY 2008

¹² Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2008 Budget Request (2007) NREL Report No. TP -640-41347 <http://www1.eere.energy.gov/ba/pdfs/41347.pdf>)

budget development, the improvements made through the Wind Energy Program represent 15% of the annual 500 million metric tons carbon equivalent savings expected from all EERE programs. This represents the highest carbon impact within the electric generation portfolio. These results suggest that continuing or expanded investment in wind energy will deliver an increasing return.

Wind energy has a clear role that can help to secure our Nation's energy economy, as has been demonstrated in Europe. In the near term, wind energy will not play a major role in this new economy, but the increases in installed capacity over the past few years indicate that the role will grow over time. Every energy paradigm change requires government understanding of the long-term implications of the change so that critical policy support can be provided during a long transition period. It is appropriate for the Federal Government to facilitate this development with sound technical assistance and R&D to remove barriers that may unnecessarily hinder this technology or the emerging industry.

Historically, Federal and state officials have used research, development, and deployment (RD&D) activities combined with financial or other policies to enhance market acceptance of new technologies. In the wind industry, RD&D has been primarily directed at reductions in the cost of the technology for both central station and distributed technologies and removing barriers to its deployment. Policy has focused on financial incentives such as the PTC to help level the playing field from a cost perspective, or state-based RPS that encourage use of the technology. These activities increase installed capacity and promote public acceptance.

As a technology becomes commercial, the greatest economic efficiency is found in an approach which balances RD&D and policies that push the technology to become competitive while encouraging adoption. For this reason, both R&D and policy support are required until wind technology can be considered mature and the need for this external support disappears.

Some have argued that the strength of the wind market, in which almost 2500 MW have been installed in the last two years, indicates that the wind industry no longer needs RD&D or policies that level the playing field. The following points illuminate the need for a continued Federal role in wind technology RD&D.

- U.S. wind energy capacity at the end of 2006 was 11,604 MW, which is less than 1% of total installed generating capacity. Given this small installed capacity, wind obviously is not a mature technology. The premise that wind is mature is likely due to comparison with other renewable energy technologies, among which wind is more mature than the others. However, compared to conventional energy technologies, wind power receives minimal support. The Federal Government expects to spend over \$10 billion on clean coal technology through 2020. The clean coal industry makes up slightly more than 50% of the nation's installed capacity. The nuclear industry represents almost 20% of installed capacity, and continues to receive extensive Federal support. Arguments that wind technology should no longer receive Federal support should be assessed in relation to all generating technologies, and not simply other renewable technologies.

- Testing wind turbines and their components for land-based, offshore, and small, distributed wind applications is required to reduce commercial risk and satisfy international and national standards. Testing centers are needed to conduct controlled research on turbine operation and use. For example, wind turbine blades are designed to withstand 20 years of high operating loads, far beyond the service life of other large structures subjected to high strains. The implementation, operation, and maintenance of test facilities require an investment in infrastructure, testing equipment, and personnel that no single industry member could sustain. Federally led, public-private partnerships (for example, the FutureGen coal technology research facility) are typically required to implement the large capital projects that enable the technology and market to develop.
- The characteristics and availability of national resources must be known for renewable-based technologies to become widely used. More information is needed about wind conditions over the United States. This information is crucial given the size of modern wind turbines and the potential market for small turbines. Atmospheric conditions such as low-level jets, low-speed turbulence, and nighttime air disturbances are not well enough understood to allow industry to define technology and siting needs. Research into these conditions has national level implications; it applies to the whole market, and can be compared to the U.S. Geologic Service's assessment of the Nation's oil and gas reserves.
- One reason for the rapid decrease in the cost of wind technology is the development of advanced wind turbine design software that has been made available to the wind industry through government laboratories. These tools have allowed industry to accurately assess the loads on wind turbines and model computer-based conceptual designs. The tools must be improved to allow accurate modeling and assessment of industry technology trends, and to allow government researchers to model different technology options, assess their potential for performance improvements, and direct Federal research. Model development and validation cannot be completed by the private sector because of obvious intellectual privacy concerns.
- Promising future technologies such as offshore wind power, conversion of wind power to hydrogen, and expansion of vehicle-to-grid and wind-to-vehicle technology all require high-risk, long-term research to enable commercial success. The Federal Government, and specifically DOE, plays a role in supporting high-risk basic energy research that may not have near-term impacts but has promising long-term potential.
- Federal organizations play an important role as an impartial independent technical advisor to facilitate discussion and help protect and educate the public. Corporate organizations and trade associations are often considered to be biased, and neutral parties are essential in providing balance in often contentious discussion on costs and benefits.
- Wind technologies raise a number of technical and social issues that must be addressed by other governmental institutions. State officials, other Federal agencies, Native American organizations, regulators, and the regional power administrators must have technical assistance to evaluate wind technology. DOE has a responsibility

to provide energy-related support to these and other governmental organizations, for wind and other technologies.

- Many of the implementation issues and barriers that hinder wind technology development cross state boundaries, and therefore, require Federal facilitation and support. The state-by-state approach to development has national implications, and a lack of Federal assistance and supervision would hamper technology acceptance.
- The domestic small-wind market does not have the capital support currently found in the large-wind market; therefore, support in the development of more reliable, more efficient and lower cost distributed wind technologies requires further assistance until the key issues are sufficiently documented to attract private equity. This becomes more critical due to the current dominant role that U.S. suppliers have in the international small-wind market, a dominance that is being eroded by expanded technology development support from other governments.

Wind energy can play an important role in reducing the nation's dependence on imported fuels, preserving the environment, and reducing the potentially devastating impact of global climate change – and it can do all this without adversely impacting consumers' pocketbooks; a true win-win-win scenario. Because of national and international interest in this capability, wind power is becoming a strong player in the world's power markets.

However, the implementation of a new technology paradigm is always difficult. Federal organizations have an important role to play in the transition to new generating technology. Through continued properly targeted and managed Federal support, the United States can lead and take advantage of this paradigm change. The 2005 Annual Energy Outlook (AEO)¹³ shows that by 2015, wind energy will be less expensive than nuclear, and practically the same price as energy from natural gas and coal, even though prices for these fuels are estimated to be less than today's in nominal dollars. Even with these conservative estimates, wind energy is expected to have a large market presence. The AEO and GPRA¹⁴ analyses indicate that without continued Federal support, implementation of wind technologies will be significantly reduced, showing a direct link between continued support and adoption of the technology by the energy sector and the general public.

¹³ *2005 Annual Energy Outlook*, Energy Information Administration,
<http://www.eia.doe.gov/oiaf/aeo/index.html>

¹⁴ *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs, FY 2006 Budget Request*, National Renewable Energy Laboratory, May 2005, NREL/TP-620-37931.
<http://pdx.nrel.gov:8020/BASIS/nich/www/nrel/SDF>

1.3 Program Vision

The Presidential Advanced Energy Initiative (AEI)¹⁵ presents a vision for the future development of wind energy by stating:

“Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States,” and increased federal funding “... will help improve the efficiency and lower the costs of conventional wind turbine technologies; it will also help develop new small-scale wind technologies for use in low-speed wind environments.”

Following the guidance of this document, and building on the domestic energy focus of EPAct 2005, the Wind Energy Program has developed a new direction for the development and deployment of wind technologies. In conjunction with AWEA and NREL, the program launched an effort to assess the potential for and impact of providing 20% of the Nation’s electrical energy from wind technology. The Wind Vision Report, the initial document developed by this collaboration, will be released in the summer of 2007. The goal of the collaborative is to rigorously investigate the viability of a vision that includes the production of 20% of the Nation’s electrical energy needs from wind technology. Following rigorous analysis and investigation of all major facets of the U.S. energy system, from power transmission to consumer acceptance, this collaborative of over 75 participating organizations has proven that wind energy can provide 20% of U.S. electricity needs by 2030, securing America’s leadership in reliable, clean energy technology. The collaborative’s report describes how as an inexhaustible and affordable domestic resource, wind strengthens our energy security, improves the quality of the air we breathe, slows climate change, and revitalizes rural communities.

At 20% penetration of the electric sector, wind will produce about 1,200 terawatt-hours (TWh) of the Nation’s electrical energy each year, eliminating 1,925 million metric tons of carbon equivalent through 2050 – equivalent to the carbon dioxide produced by the whole transportation sector during 3-1/2 years. This would also lead to approximately 332 billion dollars in economic investment and more than 2,750,000 full-time equivalent job years, largely in rural areas, for construction and plant operation over the 20-year expected operational life of each project. Many states in the Great Lakes and southeast regions could benefit dramatically from turbine component manufacturing, with 20 states gaining 20,000 or more manufacturing jobs. According to current estimates, the cost of producing 20% of the nation’s energy from wind in 2030 would add less than one dollar to the monthly electricity bills of a median American household, and could reduce the cost of natural gas used for heating by as much as 20% by reducing natural gas demand. The Wind Energy Program embraces this vision of the future of wind energy.

As the DOE Wind Energy Program plans for wind technology development, it appears that the technology will take three development paths: large land-based technology,

¹⁵ Advanced Energy Initiative, http://www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf; page 13, 2006.

distributed wind technology, and emerging applications, as shown in Figure 5. Each of these paths presents unique technology challenges and non-technology barriers.

The land-based electricity path, which is a priority for the program, is expected to result in cost-competitive 2- to 5-MW turbine technology by 2012. The land-based electricity path, which is a priority for the Program, is expected to result in cost-competitive 2- to 5-MW turbine technology by 2012. Land-based activities have focused on development of technologies that can operate cost effectively at low wind speeds, and on improving the reliability and performance of turbines in higher wind speeds. Two basic drivers contribute to the cost of wind energy: the wind resource and transmission. Figure 6 shows the supply curve for the U.S. wind resource, detailing over 12,000 GW of potential at a cost below \$0.14 cents/kWh, excluding the cost of transmission and siting factors that will limit the use of these resources. As the high wind resource locations close to loads or accessible transmission are developed, projects must move into lower resource sites and pay for the development of expanded transmission infrastructure, which increases the price of power. Figure 7 shows the supply curve with transmission costs included.

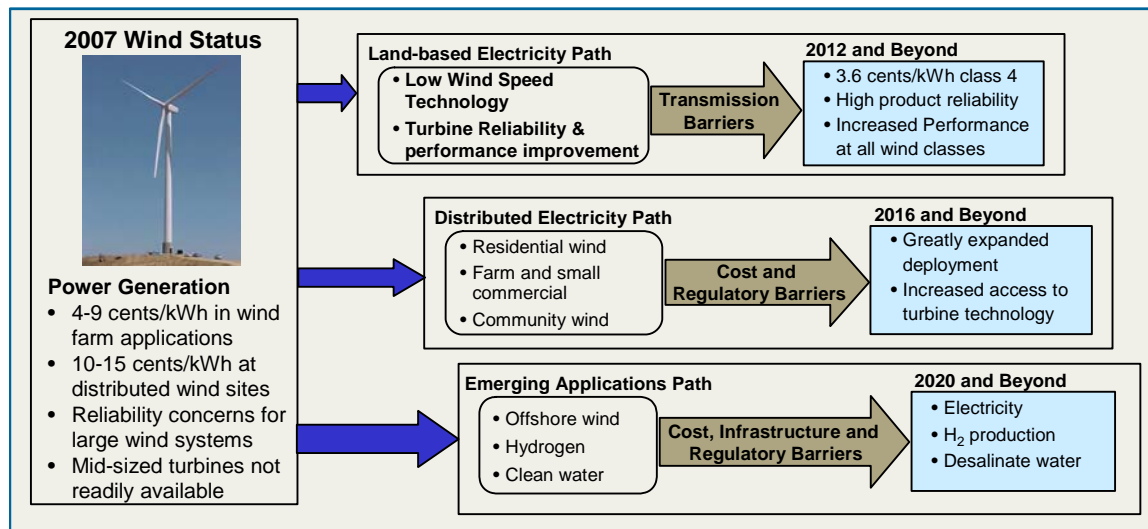


Figure 5. Three evolution pathways for wind technology development.

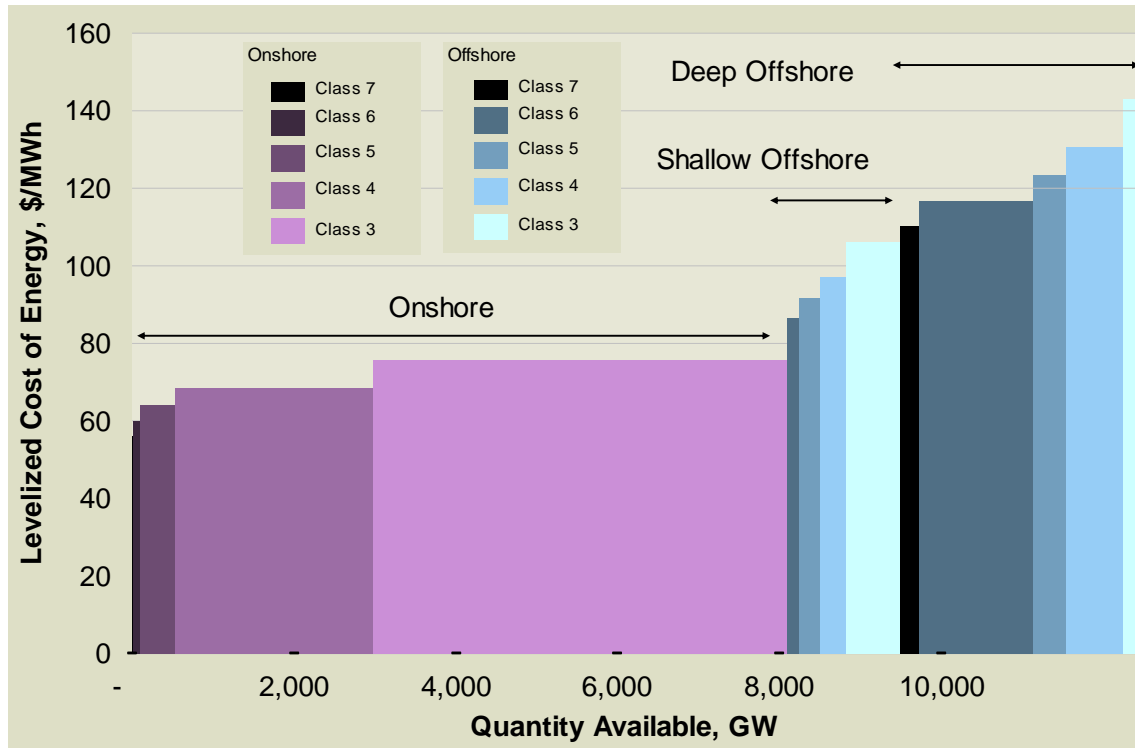


Figure 6: U.S. wind supply curve, no transmission cost (with PTC).

As the total cost increases, work to keep the cost competitive must focus on four areas:

1. Expanding the Nation's transmission infrastructure without placing the full burden of this expansion on wind project developers
2. Reducing the cost of energy from high wind resource sites through reliability and performance enhancement, to allow for higher transmission costs
3. Furthering the development of distributed wind technologies to allow communities, rural businesses, and residents take advantage of local wind resources.
4. Making lower wind resource or offshore sites cost-competitive to circumvent the need for expanded transmission.

The first option focuses on the development of energy infrastructure and is more related to policy development than R&D, especially from the perspective of the Wind Energy Program. The final three avenues follow an R&D-based technical approach, in which the cost of wind energy at all sites is reduced to allow energy to be delivered cost-competitively, first with, and later without, support of incentives such as the PTC.

Figure 6 shows that at high wind resource locations (Class 6 and above) approximately 60.7 GW of potential can be developed at relatively low cost of below 8.0 cents/kWh without the PTC or other incentives. Class 3, 4 and 5 sites allow the development of an additional 307.9 GW. Although these estimates already eliminate resources that are clearly unsuitable for development, such as National Parks, some portion of the

remaining resource will not be developed due to other siting, public acceptance, or permitting issues. Additionally, because of the geographic spread of the resources and regulations governing the electric sector, the ultimate barrier to the use of this technology is the integration of wind into the Nation's electric system.

Figure 7 shows that reaching 20% energy penetration from wind, which is estimated to require approximately 330 GW of installed capacity, will require the development of Class 4 and above sites, both land-based and offshore. The economic viability of these lower wind resource sites would open up vast resources to wind development and bring wind-generated electricity closer to major load centers. Figure 8 shows the magnitude of lower wind speed sites, and illustrates the 20-fold greater potential for wind in the United States if these sites can be used cost-effectively. These sites are closer to major load centers than Class 6 sites. The average distance between Class 6 resource areas and the 50 largest load centers is nearly 500 miles, while the average distance for most Class 4 sites is about 100 miles.¹⁶

Along with wind technology for large bulk-power generation facilities, distributed wind technologies have been a part of the program since its inception. Although current research on small wind turbines (less than 100 kW) is expected to be completed in FY 2007, opportunities for wind technology in distributed applications, either connected at distribution voltages or completely off-grid, appear to be substantial¹⁷. Technology options such as off-grid water pumping for crop irrigation, residential-scale wind turbines, community wind, or hybrid wind-diesel applications show great potential for engaging local populations in addressing America's energy future. The absence of detailed studies makes this market hard to assess, but indicators suggest that broadening distributed technologies R&D from small wind turbines may be advisable because community wind and larger distributed applications may require turbines of 100 kW to 1 MW. These turbines are not currently available from U.S. companies. The program will continue to monitor this market and determine whether developing technologies for this market is appropriate.

¹⁶ Goldman, P., et. al. Advanced Low Wind Speed Technology Research and Development in the U.S. Department of Energy Wind Program, Proceedings of the 2002 Global Windpower Conference, Paris, France, April 2002. (Available on request)

¹⁷ U.S. Small Wind Turbine Industry Roadmap. (2002). 36 pp.; NREL Report No. BK-500-31958; DOE/GO-102002-1598 <http://www.nrel.gov/docs/gen/fy02/31958.pdf>

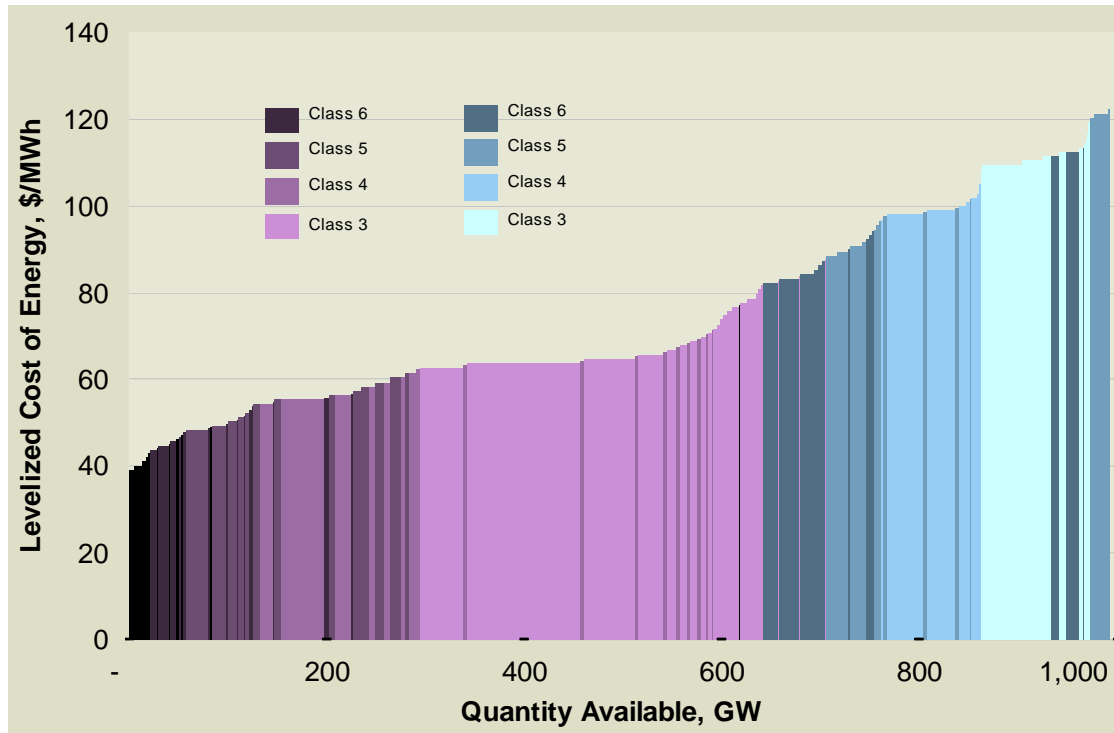


Figure 7: Wind energy supply curve, including transmission costs (2005 costs and performance, with PTC)

Given the program realignment and overall budget priorities, the program is placing less emphasis on offshore generation R&D activities. Through 2009, the program's offshore wind technology priorities are to better understand the challenges and benefits of developing the Nation's offshore resources, and to work with other Federal organizations, such as the Mineral Management Service, to produce a regulatory framework for future development. Although there are a large number of positive aspects of offshore wind energy, such as the proximity to coastal load and access to large-scale transmission, there are also issues, such as increased costs, higher risk, and the general availability of good land based resources, that might deter the market. Because of these issues, a programmatic decision will be made in FY 2009 to determine if there is sufficient market interest and a defined government role to support offshore wind. If government can play a role, the program will launch a series of phased public-private partnerships for offshore wind technologies, similar to those successfully employed for land-based applications.

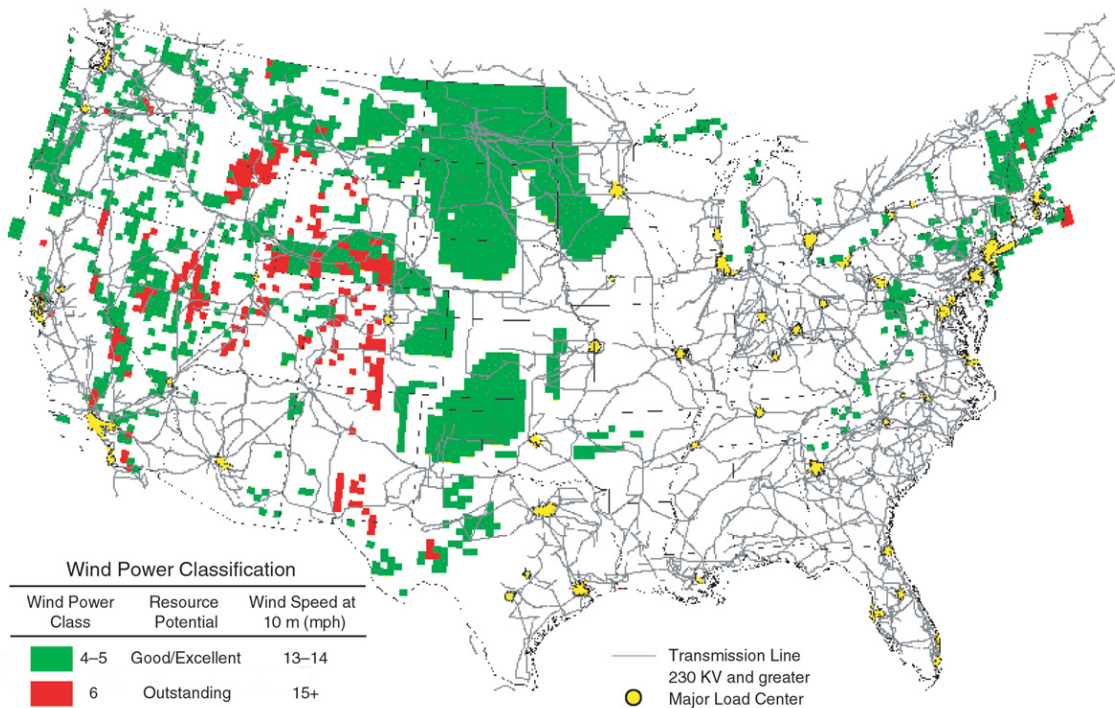


Figure 8. Wind resource, transmission, and load centers

The emerging applications path leads to tailoring of wind energy for emerging applications, such as expanded transitional and deepwater offshore technologies, hydrogen production, production and delivery of clean water, and integration of wind with other energy technologies such as hydropower. The huge transitional and deepwater offshore resource provides an opportunity for the production of power that is close to load centers, out of public sight, and has low environmental impacts, if it can be developed at a competitive cost with acceptable operational risk. Hydrogen production would enable wind to provide low-cost clean energy for the transportation sector. Finally, water is becoming a critical issue in America's west, providing a major opportunity for wind technologies both on and off the grid. Wind energy uses no water, and it can reduce the use of fossil-fueled power generation that consumes between 400 and 600 gallons of water per megawatt-hour. All of these applications present new challenges to the wind community, and cost and infrastructure barriers are expected to be significant. The program's vision is that this evolutionary pathway will begin to impact the marketplace after 2020.

Each of the technology pathways will require the program to address specific acceptance barriers. The program will continue to coordinate technical and acceptance activities as each of the new pathways is developed and implemented.

1.4 Program Mission

The Wind Energy Program's mission is to:

“support the President’s National Energy Policy and Departmental priorities for increasing the viability and deployment of renewable energy; lead the Nation’s efforts to improve wind energy technology through public-private partnerships that enhance domestic economic benefit from wind power development; and coordinate with stakeholders on activities that address barriers to the use of wind energy.”

To achieve the mission as stated in the NEP, the Wind Energy Program will conduct near- and long-term research to solve technology issues and maintain U.S. industry momentum as a technological innovator. The program will also work with the wider energy industry, governments at the state and Federal levels, and the public to ensure that wind technology is assessed fairly based on its benefits and impacts when compared to other alternative and conventional energy generation technologies. Through research on transmission, system integration, and technology acceptance, the program will work to remove barriers that limit the widespread adoption of wind technology.

The natural variability of the wind resource raises concerns about how wind can be integrated into routine grid operations, particularly with regard to regulation, load following, scheduling, line voltage, and reserves. A lack of information in these areas is inhibiting market acceptance and hindering development. Through close collaboration with industry, utilities, and government organizations at the state and Federal levels, the program is addressing wind turbine interconnection issues and the transmission of wind energy from rural wind resources to regional or national load centers. This process provides tools, clear information, and documented experience to a wide range of stakeholders in the energy community, so that educated decisions can be made regarding the use of wind technologies.

Wind energy acceptance is largely achieved through outreach activities at the state and local level. The program's Wind Powering America project eases market barriers through outreach, policy support, and the development of informational documentation regarding the benefits and impacts of wind technology, and seeks to enable a sustainable U.S. wind market beyond states with significant installed capacity, stimulate rural economic development through project development, enhance tribal energy self-sufficiency, and explore emerging markets and applications. Although closely aligned with the program's system integration activities, the activities conducted through the Wind Powering America project strive to address more general concerns with the use of wind technology.

In addition, the program supports the development of the industry-led Wind Vision Report that considers the possibility and impacts of generating 20% of the nation's electric generation from wind sources by 2030.

1.5 Program Design

The Wind and Hydropower Technologies Program was created as a result of a reorganization of EERE, which combined the wind and hydropower program areas. The two formerly separate programs have an integrated management structure, with similar program structures devoted to the Department's two key priorities of increasing the viability and application of renewable energy. Integrating the programs provides opportunities to use both established renewable energy technologies synergistically. Hydropower resources can be operated to provide an element of dispatchability to wind power, while wind power can support innovative strategies to balance power production with agricultural and environmental interests. Although DOE has concluded most of its activities in the area of hydropower technologies, leaving further development to industry, the program is researching the potential for synergies of wind and hydropower. The program will continue to assess hydropower opportunities, including but not limited to pumped hydro and promising wave, tidal, and ocean current energy technologies.

1.5.1 Program Structure

The Wind Energy Program undertakes two key activities to carry out its mission: increasing the technology viability (TV) of wind systems through technology R&D, and increasing wind energy deployment in the marketplace through technology acceptance (TA) activities. Figure 9 depicts the four primary activities within these two key areas that comprise the Wind Energy Program.

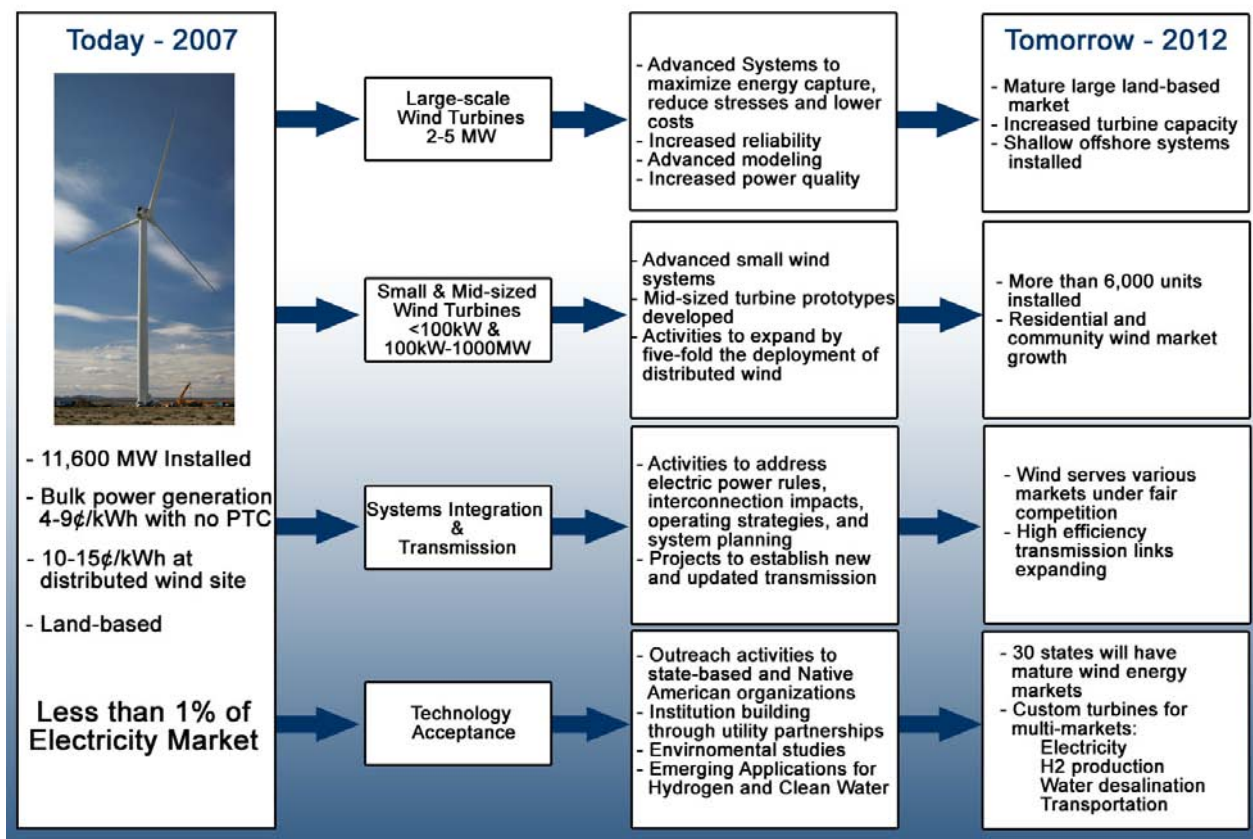


Figure 9. Key program activities.

Under Technology Viability, the program sponsors R&D on large-scale wind technology (LWT) and smaller distributed wind technology (DWT). Under Technology Application, the program sponsors research on transmission and systems integration (SI) and the more general technology acceptance (TA) outreach activities. The program also conducts supporting research, development, and application testing to align program efforts with the key activities and the goals that they support.

1.5.2 Program Logic

The program logic model in Table 2 provides a brief overview of the program's key activities and demonstrates how they are designed to meet overall program goals.

Table 2. Program Logic Model for Wind Program				
Project	Large Wind Turbine Technology	Distributed Wind Technology	Transmission & System Integration	Technology Acceptance
Resources	<ul style="list-style-type: none"> • Appropriations • Industry cost sharing • NWTC facilities • IEA 	<ul style="list-style-type: none"> • Appropriations • Industry cost sharing • NWTC facilities 	<ul style="list-style-type: none"> • Appropriations • State funds • Partners 	<ul style="list-style-type: none"> • Appropriations • State funds (energy offices) • Partners
Activities	<ul style="list-style-type: none"> • Technology development through public-private partnerships. • Supporting research and testing. • Reliability and performance improvement for existing turbine technologies. • Low wind speed technology development. • Offshore wind and resource assessment. 	<ul style="list-style-type: none"> • Technology development through public-private partnerships. • Supporting research and testing. 	<ul style="list-style-type: none"> • Wind generator modeling. • Wind farm data monitoring. • Resource characterization. • Grid operational impact analysis. • Transmission and generation planning. • Grid rules development. • Institution building through utility partnerships. 	<ul style="list-style-type: none"> • Outreach to state-based organizations. • Small wind. • Institution building through utility partnerships. • Support for Native American interest in wind power. • Environmental and siting mitigation. • Emerging applications. • Resource Assessment.
Outputs	<ul style="list-style-type: none"> • New components, concepts and wind systems for land-based applications in Class 4 wind regimes. • Basic research tools to assist industry. • COE 3.6 cents/kWh in Class 4 wind by 2012. • Better understanding of offshore wind energy market and technical challenges. • COE 5 cents/kWh in Class 6 wind in shallow water by 2014. 	<ul style="list-style-type: none"> • By 2015 expand by five-fold the number of distributed wind turbines deployed in the U.S. market from a 2007 baseline. • New components, concepts and wind systems for applications of less than 100 kW. • Development of wind turbines to support mid-sized market applications. 	<ul style="list-style-type: none"> • Ability of wind systems to compete without disadvantage in key areas of market rules, interconnection impacts, operating strategies, and system planning. • Development of new transmission to facilitate wind development. 	<ul style="list-style-type: none"> • 30 states with mature markets that support wind industry growth. • Technical and outreach support widely available. • Fewer barriers to large and small wind integration.
Short-term Outcomes 2007–2010	<ul style="list-style-type: none"> • The use of wind energy in high and low resource areas accelerates due to their improved cost effectiveness. 	<ul style="list-style-type: none"> • Wind turbines for residential (1-2 kW) use and commercial/community applications (100 kW and above) enter the marketplace. 	<ul style="list-style-type: none"> • Wind becomes a participant in defining the national needs of emerging grid operation and rulemaking processes. • Announcement of 3 new transmission lines to bring low-cost wind to urban load centers. 	<ul style="list-style-type: none"> • 30 states achieve a level of public awareness and policy environment that fosters a vibrant market for wind energy development.
Intermediate Outcomes 2010–2020	<ul style="list-style-type: none"> • The use of wind energy as a low-cost electricity source, without financial incentives, becomes widespread as technology matures. • Commercial development of shallow water technologies. • Commercial wind turbine technology for transitional water depths is developed and demonstrated in offshore sites. 	<ul style="list-style-type: none"> • Distributed uses of wind energy at all sizes emerge as a significant opportunity for technology deployment and end-users embrace wind for a growing number of uses. 	<ul style="list-style-type: none"> • Utilities and developers gain clear understanding of barriers to integration and know how to address them. • Increased transmission implemented allowing the expanded use of wind technologies. 	<ul style="list-style-type: none"> • Public acceptance of wind technologies in rural areas, supporting local economic development. • 6-8 regional wind collaborative organizations emerge and function to plan and integrate appropriately large amounts of wind energy into regional operating systems.
Long-Term Outcomes and Problem Solutions 2020 and beyond	<ul style="list-style-type: none"> • The percentage of energy generated from wind exceeds 10%, confirming wind as a major National energy source. • Wind turbine technology for use in deepwater offshore applications is proven economic and becomes a major new electricity source for states bordering coastal zones. 	<ul style="list-style-type: none"> • Wind turbines for emerging applications become available and gain acceptance for specialized uses such as hydrogen production and water supply. 	<ul style="list-style-type: none"> • Wind achieves high grid penetration level and is a nationally accepted part of our energy portfolio. • National transmission infrastructure allows high levels of wind penetration. 	<ul style="list-style-type: none"> • Awareness and acceptance levels are achieved nationally, making further coordination efforts unnecessary.

1.5.3 Relationship to Other Federal Programs

In seeking to lower barriers to the deployment of wind energy, the Wind Energy Program has developed key working relationships with other EERE, DOE, and Federal programs. Each of these organizations has a unique role to play in making wind a part of the National energy supply portfolio.

Because the Federal government is the largest user of energy in the world, its use of wind power can play an important role in expanding wind markets. Federal facilities are beginning to look to wind as a source of clean power. In general, Federal facilities are not owners of wind plants, but agree to purchase power from those plants. The Wind Energy Program works with the Federal Energy Management Program (FEMP) to foster use of wind power by Federal agencies.

The program has also forged numerous partnerships with other Federal agencies as it pursues the grid integration needs of the wind community. For example, the Wind Energy Program worked with the Office of Electricity Delivery and Energy Reliability to prepare a joint report to Congress¹⁸ on the location of wind resources in the upper Midwest. The report is being extended to include the expansion of the National transmission infrastructure to bring large amounts of low-cost wind energy from rural areas to national load centers.

In addition, the SI staff work with other Federal entities, such as the Bonneville Power Administration (BPA) and the Western Area Power Administration (Western), to understand both general regional wind integration issues and wind-hydropower integration issues. Program and laboratory staff members have worked with staff members from the Federal Energy Regulatory Commission (FERC) to help them better understand wind energy characteristics (FERC provides oversight to the national grid system and establishes rules for the future grid treatment of wind).

The program has become increasingly involved in environmental issues associated with siting for both land-based and offshore projects. A key example of this is the program's collaboration with the Federal Aviation Administration, Department of Homeland Security, and the Department of Defense (DoD) to address issues with wind turbine/radar interactions. This has led to the development of an interagency collaboration on wind turbine siting. Program members are also working with the Department of Interior's (DOI's) Minerals Management Service (MMS) to coordinate interagency efforts to open Federal lands to responsible renewable energy development and develop a regulatory framework directly applicable to offshore wind energy projects in Federal waters. Similarly, the program is partnering with the DOI Bureau of Land Management (BLM) to develop resource assessments and to design and implement policies and procedures to open BLM-managed lands to responsible wind energy development, primarily in the western United States.

¹⁸ *Analysis of Wind Resource Locations and Transmission Requirement in the Upper Midwest*. June 2004, <http://www.nrel.gov/wind/uppermidwestanalysis.html>

An important success related to public lands was achieved in 2003 when the BLM adopted procedures that include wind in BLM's long-term land plans and allow programmatic environmental impact statements to streamline siting processes. These changes, advocated by the Wind Energy Program and officially supported via technical assistance and funding, should facilitate the use of wind power on Federal lands. This effort will also serve as a model for other Federal agencies, such as the U.S. Forest Service and USDA, and for state public lands administrators.

The program cooperates with the DOI Fish and Wildlife Service (FWS) to examine and develop responsible development practices for species under its stewardship. It participates in an FWS, industry, and environmental stakeholder partnership to study wind-bat interactions in the mid-Atlantic region.

To reduce market barriers, the program has been cooperating with the USDA's Rural Business-Cooperative Service to provide outreach and technical assistance in support of Section 9006 of the Farm Bill, which provides grants to rural small businesses to stimulate investment in renewable energy and energy efficiency systems.

In emerging applications, the program is participating in the Sustainable Water Resources Roundtable, which is composed of government (DOE, USDA, Army Corps of Engineers, DOE, Environmental Protection Agency [EPA], National Oceanic and Atmospheric Administration [NOAA], and states), industry, environmental, public interest groups, and academic representatives. Program members have also had discussions with the U.S. Bureau of Reclamation about partnering on wind-powered desalination.

Program members coordinate with the DOE Hydrogen Program to ensure that wind-generated hydrogen is included in that program's planning. NREL's National Wind Technology Center (NWTC) staff is working with the Hydrogen, Fuel Cells, and Infrastructure Technologies Program (HFCITP) to test electrolyzers operating with variable power input, which could be a future wind application. The Wind Energy Program also coordinates the response to informational requests regarding wind and hydrogen as a result of EPAct 2005.

Working relationships with Federal programs and agencies outside of DOE are required to overcome specific technical barriers, because these organizations have critical technical skills. For example, NOAA, which operates the Forecast Systems Laboratory (FSL) in Boulder, Colorado, works with Wind Energy Program researchers to develop advanced forecasting techniques and products using the FSL's state-of-the-art numerical weather prediction model. At the USDA's Agricultural Research Center in Bushland, Texas, the program sponsors wind technology development for agricultural applications, such as irrigation and farm power, and for hybrid systems (e.g., wind-diesel) for distributed and remote applications.

As part of its TA effort, the program also works with NWCC and UWIG to form partnerships with public power organizations, such as the American Public Power

Association (APPA) and the National Rural Electric Cooperative Association (NRECA), to build momentum for utility acceptance and support for wind-grid integration.

1.6 Wind Energy Program Goals and Multiyear Targets

The DOE Strategic Plan, published in 2003,¹⁹ describes four strategic goals that support the Department's mission. These goals are in the areas of defense, energy, science, and the environment. The energy strategic goal is directly relevant to the Wind Energy Program. All of the Wind Energy Program's efforts support that goal, as shown in Figure 10.

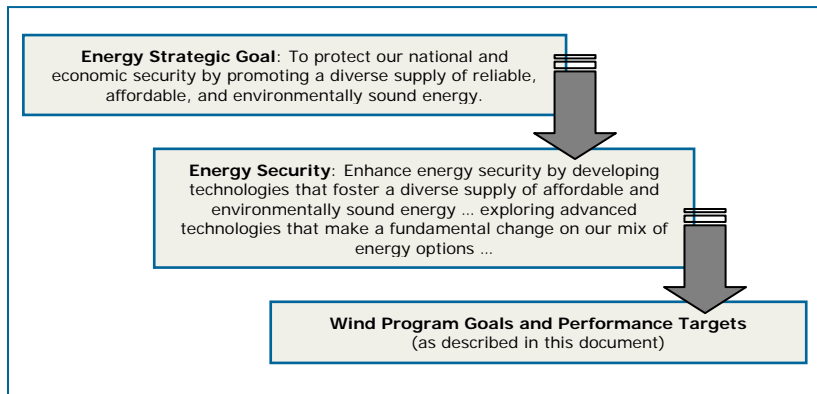


Figure 10. Relationship of Wind Program goals to DOE strategic goals.

EERE leads the Federal Government's RD&D efforts in energy efficiency and renewable energy. EERE's Strategic Plan, published in 2002,²⁰ describes nine strategic goals. These include reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, increasing the efficiency of buildings and appliances, reducing the energy intensity of industry, and creating a domestic renewable energy industry. Most relevant to the Wind Energy Program is the priority to:

Increase the viability and deployment of renewable energy technologies, by improving performance and reducing costs, and by facilitating market adoption of renewable technologies.

1.6.1 Program Strategic Goals

“By 2016, complete program technology R&D, technical support, collaborative efforts, and outreach needed to overcome barriers (energy cost, energy market rules and infrastructure, and energy sector acceptance) to allow wind energy to compete with conventional fuels without disadvantage in serving and meeting the Nation's energy needs.”

¹⁹ The Department of Energy Strategic Plan, August 6, 2003, http://www.nti.org/e_research/official_docs/doe/doe080603.pdf

²⁰ U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Strategic Plan 2002, http://www.eere.energy.gov/office_eere/strategic_plan.html

1.6.2 Program Performance Goals

The program has defined performance goals shown in Table 3 for its TV and TA activities that will position wind as an attractive advanced technology option for the twenty-first century.

	Table 3. Performance Goals
2007	<ul style="list-style-type: none"> Reduce the cost of electricity from distributed wind systems to 10-15 cents/kWh in Class 3 wind resources.
2010	<ul style="list-style-type: none"> Facilitate the installation of at least 100 MW of wind energy in 30 states.
2012	<ul style="list-style-type: none"> Reduce the cost of electricity from large wind systems in Class 4 winds to 3.6 cents/kWh for onshore systems.
2012	<ul style="list-style-type: none"> Complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the Nation's energy needs.
2014	<ul style="list-style-type: none"> Reduce the cost of electricity from large wind systems in Class 6 winds to 7 cents/kWh for shallow water (depths up to 30 meters) offshore systems (from a baseline of 9.5 cents/kWh in 2005).
2015	<ul style="list-style-type: none"> Expand the number of distributed wind turbines deployed in the U.S. market fivefold from a 2007 baseline.

Life cycle cost of energy (COE) has been adopted by the Wind Energy Program as the primary means of measuring the program's progress toward achieving its goals. This methodology is consistent with that used in other bulk power generating technologies, such as coal or nuclear. The specific methodology used for calculating COE for onshore and offshore installations is described in the draft version of the *Primer: The Wind Energy Program's Approach to Calculating Cost of Energy*. In this methodology, all costs are presented in fixed-year dollars to aid in comparison between different technologies and to remove price fluctuations over time due to inflation and commodity price changes. It should be noted that the COE reported here does not represent a market cost, but rather a cost-based technology metric used to track long-term progress toward the program's technology-based goals. The COE targets differ from actual market conditions, as baseline technology assumptions do not include such factors as the on and off nature of the PTC that leads to turbine demand spikes; changing financial variables such as interest rates; fluctuating commodity prices and currency exchange rates; and

changes in expected equipment life. The real cost of power from wind energy varies between 4 and 12 cents/kWh, depending on the resource and the specific financing structure of the specific project.

1.6.3 Program Multiyear Targets

Program Outputs

The outputs for the Wind Energy Program are the Joule milestones designated annually for each program area. (Joule is a system used by DOE to track the progress of technology programs.) Successful achievement of the milestones provides new components and systems that position the wind industry to compete without subsidies in the full range of U.S. electricity markets. Past milestones led to the development of General Electric's (GE's) highly successful 1.5-MW S-Series turbine that supplied more than half of the capacity added to the grid in 2003. Achievement of 2004 milestones accelerated the development of a 2.5-MW Liberty turbine for Clipper Windpower, which began manufacturing in 2005 and full-scale production in 2006.

For TA, the expected outputs will be in the form of information and technical support needed to address integration barriers such as market rules, interconnection impacts, operating strategies, and system planning, as shown in Table 5. In addition to reducing integration barriers, the program is addressing more general legal, institutional, and zoning barriers, allowing informed decision-making in processes that evaluate wind for land-based, offshore, and distributed applications.

Table 4. Technology Viability Outputs 2007 - 2012

- Expanded turbine performance and reliability improvements implemented in turbine technology for all wind regimes.
- Complete field-testing performance documentation of the sub-scale wind turbine research-blade series
- Continue collaboration with wind plant operators to determine operations and maintenance experience and target reliability enhancements
- Complete tradeoff studies for offshore wind turbine systems while developing information required for the program to make an accurate assessment of further DOE involvement in the 2009 timeframe.
- Fund a second round of small wind turbine concept, component, and system prototype projects that focus on improving product reliability, performance, and cost.
- Issue a solicitation for prototypes aimed at improving cost and performance for larger turbines to support the wider distributed wind market.
- Initiate laboratory and field-testing activity to verify distributed wind technology's ability to meet the requirements of state and other renewable incentive programs.

Table 5. Technology Application Outputs 2007 - 2012

- Conduct large-scale wind plant operational studies in conjunction with regional transmission system, utility, and wind plant operators.
- Develop mitigation strategies and guidelines for adverse impacts for use by regional transmission organization staff and wind plant operators.
- Evaluate simulation tools developed to represent several geographically diverse wind plants connected to the same power system to provide an analytical basis for integration of larger amounts of wind energy.
- Launch a new regional wind support effort with expanded support for state wind working groups, tribal wind energy development projects, partnerships with agricultural sector organizations, and community and rural school wind projects.
- Increase efforts to assess and mitigate environmental impacts of wind turbines by funding collaborative research activities such the Grassland and Shrub-Steppe Species Collaborative; working with Department of Interior to develop siting guidelines; and producing technical and outreach materials on environmentally sensitive ways to develop wind.

Program Outcomes

The Wind Energy Program will contribute to our national security and economy, while benefiting the environment. The Great Plains region, which has been dubbed “the Saudi Arabia of wind” because of its tremendous untapped wind energy potential, offers domestic energy that can increase our national energy security and strengthen our energy infrastructure by diversifying our energy supplies. Reliance on indigenous resources also reduces the balance of payments that threatens our national economic security. Because wind energy’s fuel is free, it reduces the risk associated with volatile fossil fuel prices. Wind displaces electricity that would otherwise be produced by burning natural gas, thus helping to reduce gas demand and limit gas price hikes. According to the NEMS-GPRA 06 model²¹, with the realization of the Wind Program’s goals, wind energy will displace 2.29 quadrillion Btu (equivalent to 298 GWh) of non-renewable generation per year by 2020.

The successful achievement of the Wind Energy Program’s goals will lead to several positive environmental outcomes, one of which is the displacement of carbon emissions. According to the GPRA report, wind energy could displace 52.4 million metric tons of carbon equivalent per year by 2020. Table 6 shows the projected incremental benefits of DOE-supported program activities for the FY 2008 budget request.

Specific short-, medium-, and long-term outcomes can be found in Table 2.

Table 6. GPRA Projections for the FY 2008 Wind Energy Program Budget Request (incremental benefits of DOE-supported program activities)					
Metric	2010	2020	2030	2040	2050*
Additional GW installed	0.7	46	52	130	177
Avoided carbon emissions, annual (MMTC)	1	30	36	113	139
Consumer savings, annual (bil. 2004\$)	--	9	8	12	-4 ^a
Electric power industry savings, annual (bil. 2004\$)	-0.1	4	3	9	3
Energy intensity reduced (% change in E/GDP)	0.0%	0.7%	0.7%	2%	2%

^aThe drop in the price of electricity causes a small shift towards less expensive and less efficient end-use equipment. This results in increased consumer savings in investment costs throughout the timeframe (especially 2030 on). However, by the end of the modeling period (i.e. 2040 to 2050), the average electricity price begins to increase, which results in negative consumer savings. The increase in electricity price is caused by increasing investment costs in the electric sector for both wind turbines and backup combustion turbines.

²¹ *Project Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2006 Budget Request*, National Renewable Energy Laboratory, Golden, CO. NREL/TP-620-37931, May 2005.



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